COLOR TELEVISION CHROMA REFERENCE SYSTEMS USING THE μA703*

by Larry Blaser and Norm Sturn

INTRODUCTION

Accurate reproduction of a televised color image requires the regeneration at the receiver of a 3.58-MHz subcarrier frequency in exact phase with the color burst reference signal transmitted by the station during a portion of the horizontal blanking time.

Three methods are used to re-establish the 3.58-MHz subcarrier in present color receivers: (1) the voltage controlled crystal oscillator in an APC loop; (2) the injection locked crystal oscillator; and (3) the narrow bandpass crystal-ringing circuit. The most familiar is the crystal oscillator in an APC loop. This system has a wide pull-in range, excellent phase stability, and high noise rejection, but requires an external phase detector and frequency controlling element such as a reactance transistor or varicap. The simpler injection-locked oscillator system does not require an APC loop. In this system, the burst is transformer-coupled directly into the oscillator to lock it. The injection locked system, however, compromises phase stability and noise immunity.

For good noise immunity, the circuit Q must be extremely high, which requires that the crystal oscillator have lower drift than is required in the APC system for acceptable phase stability. Because the system has an output level which is disturbed during burst injection, the circuitry that it drives must be able to accommodate amplitude variations of the reference signal. The ringing system relies on a high Q crystal filter which is energized during the burst period. It continues to ring during the remainder of the horizontal period until reinforced by the next burst. Of the three systems, it is the only one which does not require a killer, since there is no demodulation drive in the absence of a burst. However, because it has no output in the absence of a burst, it is not suitable for driving certain types of demodulators.

Designs of voltage-controlled and injection-locked crystal oscillators using the μA703 integrated circuit are described in the paper.

INTEGRATED CIRCUIT μA703

The μA703 integrated circuit has been specifically designed for self-limiting applications. In an oscillator circuit, the output voltage level is determined by the load and is independent of the feedback signal, provided that this signal is sufficiently large. Biasing is incorporated within the device, so that a minimum of external components are required in either amplifier or oscillator applications. The device is described in greater detail in the literature.[1]

VOLTAGE-CONTROLLED CRYSTAL OSCILLATOR FOR APC SYSTEM

Fig. 1 shows the μA703 integrated circuit and associated circuitry for a voltage-controlled crystal oscillator. The positive feedback voltage to start and sustain oscillations is taken from a capacitive tap in the tuned circuit at the collector of transistor Q_B. This voltage is fed back through a narrow bandpass filter to the base of transistor Q_A. The common-collector transistor, Q_A, drives the common-base transistor, Q_B, to complete the regenerative feedback path required for oscillation.

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* As originally published in EDN, March 1967.

1. Barrett, Blaser, and Suzuki; "An FM Tuner Using MOS-FET'S and Integrated Circuits", IEEE Transactions on Broadcast and Television Receivers, pp 24-32; July 1965. Also avaliable as Fairchild Semiconductor Technical Paper, TP-21.

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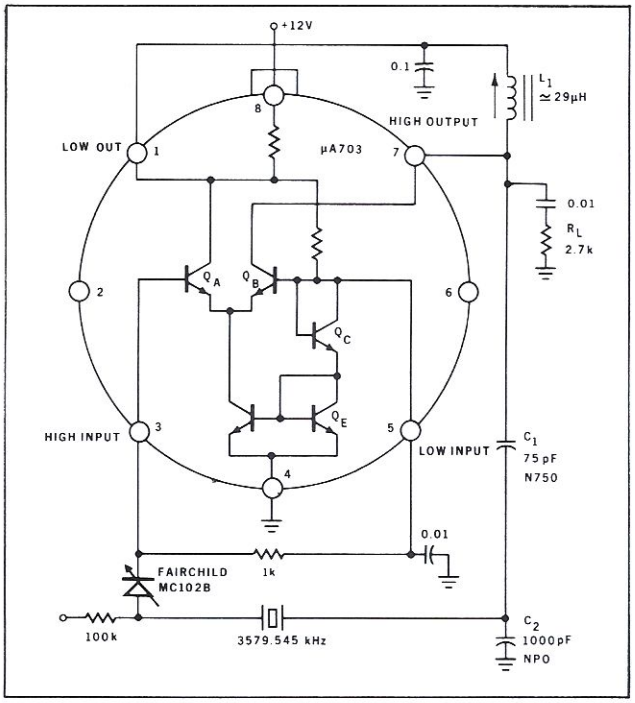

Fig. 1. Integrated circuit, voltage-controlled crystal oscillator.

The inductor, L_1, in combination with the series capacitors, C_1 and C_2, make up the reactive components of the temperature-compensated, 3.58-MHz output tank circuit. The output signal amplitude (V peak - 5 volts) is determined by load resistance, R_L. The loaded Q of the output tank is approximately 5. The inductor, L_1, provides a ±400 cps oscillator frequency adjustment range with less than a 1-db change in output level. The range of +400 cps is more than sufficient to accommodate the tolerances of all frequency-determining components, the more predominant ones being ±0.005 percent crystal and the ±10 percent varactor diode in the feedback circuit. A relatively large feedback signal (0.5 volt peak-to-peak) is fed into the high input of the integrated amplifier to take advantage of its self-limiting properties. The crystal in the feedback circuit is the primary frequency stabilizing element. It operates in the inductive mode and resonates with the capacitance of the varactor diode. The voltage-dependent capacitance of the diode provides a fine frequency control.

The low input of the μA703 sets positive above ground by the forward voltage drops of the two diode-connected transistors, Q_C and Q_E. The 1-kilohm resistor from the "high" to "low" inputs of the μA703 provides base current for transistor Q_A, and is the predominant load on the series resonant feedback circuit.

The "high" input which also sets 1.5 volts above ground provides an excellent voltage reference point for the varactor diode because of the small change in voltage at this point with variations in temperature and V_{CC}. The variactor diode has a nominal capacity of 30 picofarads at 1.5 volts reverse bias and $\frac{C_{2V}}{C_{40V}} \leq 3.1$. With a 1.5-volt reverse bias on the diode, a plus or minus 1-volt control voltage, which changes the capacitance appreciably, can be applied without forward biasing the diode. Because the diode always operates reversed-biased, it can be driven from a high-impedance phase detector.

INJECTION-LOCKED CRYSTAL OSCILLATOR

Fig. 2 shows the μA703 integrated circuit and associated circuitry for a injection-locked crystal oscillator, which is basically similar to the voltage-controlled oscillator. The output tuned circuit is the same, except that the ratio of C_1 and C_2 is smaller to allow for the additional voltage drop of the burst transformer impedance in the feedback loop. L_1 provides the initial frequency setup without affecting the output voltage significantly. The crystal in the feedback loop is the primary frequency-determining element. It operates in an inductive mode and resonates with capacitor C_3. The burst transformer induces the chroma reference synchronizing voltage into the feedback loop of the oscillator. It is parallel resonant and is tuned for maximum burst amplitude. The total reactance of the feedback loop will be changed during the injection period depending on the frequency difference between the oscillator and the induced voltage. The oscillator will tend to look to the induced synchronizing voltage if the ratio of induced voltage to the feedback voltage is large and the frequency difference between the oscillator and induced voltage is small. These two factors will further in-

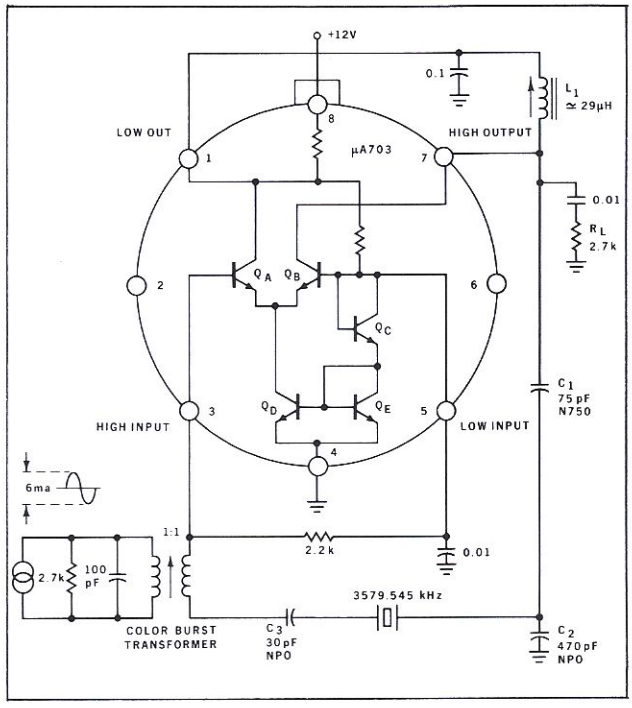

Fig. 2. The μA703 injection-locked crystal oscillator.

fluence the phase relation between the oscillator and the reference burst in the locked position.

It has been determined by controlled viewing tests of color scenes that the maximum tolerable phase error in the chrominance signal (or in the regenerate color reference signal) is approximately ±15 degrees.[2] For the burst injection system shown in Fig. 2, it was determined experimentally that a burst voltage injected across the crystal and C_3, which is six times the amplitude of the feedback signal at C_2, would hold the phase error of the locked oscillator to within ±15 degrees for a 100-cps change in oscillator free-running frequency. Since measured oscillator drift due to all causes is considerably less than 100 cps (Figs. 7 and 8), the expected tint shift in normal set operation would be quite acceptable.

The 6-mA peak-to-peak drive current required at the primary of the burst transformer can easily be developed by using another μA703 as a burst amplifier.

VOLTAGE-CONTROLLED CRYSTAL OSCILLATOR PERFORMANCE

The voltage-controlled oscillator frequency and output amplitude versus V_{CC} is shown in Fig. 3. The frequency drift of the oscillator for changes in ambient temperature is

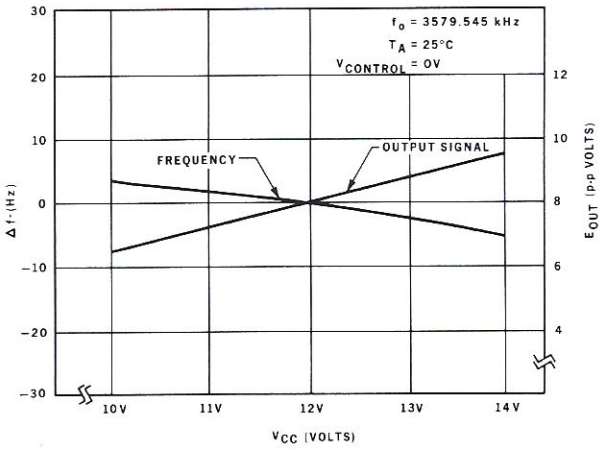

Fig. 3. Frequency and E_{out} versus V_{cc}, voltage-controlled oscillator.

dependent upon the type of crystal used and the overall layout of the circuit. Fig. 4 shows frequency drift versus temperature, with the oscillator being temperature-compensated for only one particular type of crystal in a breadboard layout.

2. Donald G. Fink, "Television Engineering Handbook"; McGraw-Hill Book Company, pp 9-30 to 9-32; 1957.

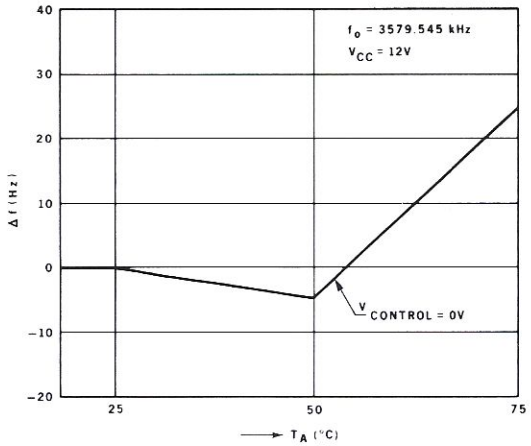

Fig. 4. Frequency versus temperature, voltage-controlled oscillator.

Oscillator sensitivity versus control voltage is shown in Fig. 5. The small control voltage needed to compensate for the oscillator drift due to all causes is easily achieved in a phase detector circuit. Table I shows oscillator frequency for several μA703's with no circuit readjustments.

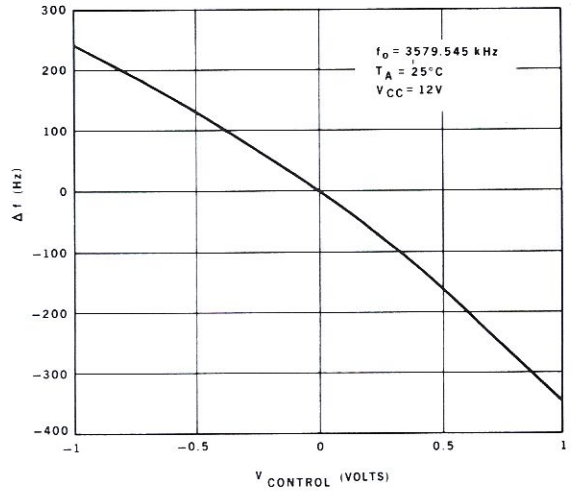

Fig. 5. Oscillator sensitivity for APC, voltage-controlled oscillator.

TABLE I.

Voltage-Controlled Oscillator--Frequency Variations with Several μA703's.

μA703 NO.	FREQUENCY OSCILLATOR(kHz)
1	3579.545
2	3579.520
3	3579.543
4	3579.500
5	3579.540

Conditions: V_{CC} = 12 V, T_A = 25°C, $V_{control}$ = 0V

NOTE: No circuit readjustments.

INJECTION-LOCKED CRYSTAL OSCILLATOR PERFORMANCE

In the absence of a synchronizing burst, the injection-locked oscillator frequency and output amplitude versus V_{CC} is shown in Fig. 6. Oscillator frequency versus ambient

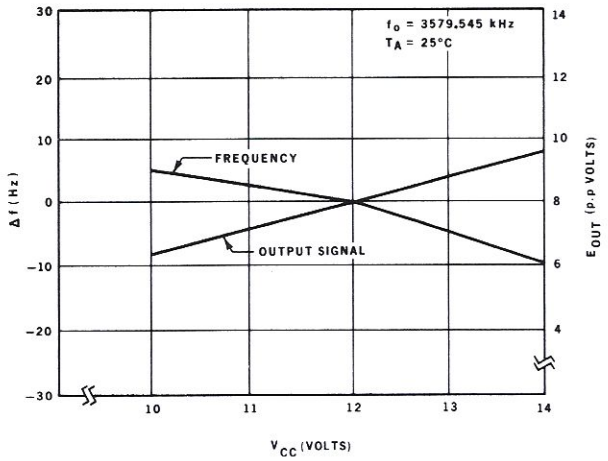

Fig. 6. Frequency and E_{out} versus V_{cc}, injection-locked oscillator.

temperature is shown in Fig. 7. With a burst voltage injected across the crystal, and C_3 six times the amplitude of the feedback signal at capacitor C_2, the measured phase

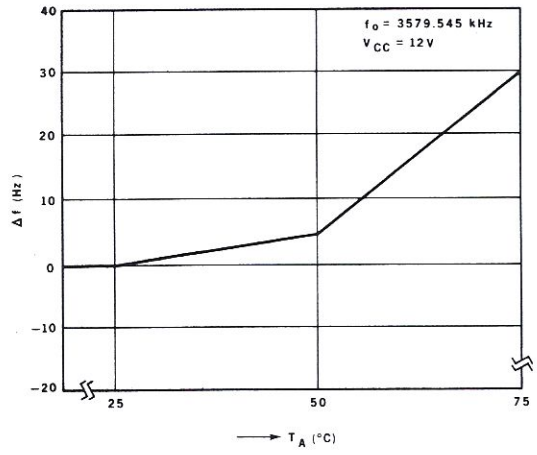

Fig. 7. Frequency versus temperature, injection-locked oscillator.

shift between burst and oscillator signal versus free-running oscillator frequency is shown in Fig. 8. Pull-in capability of the circuit with a 6:1 injection ratio is ±400 cps which is

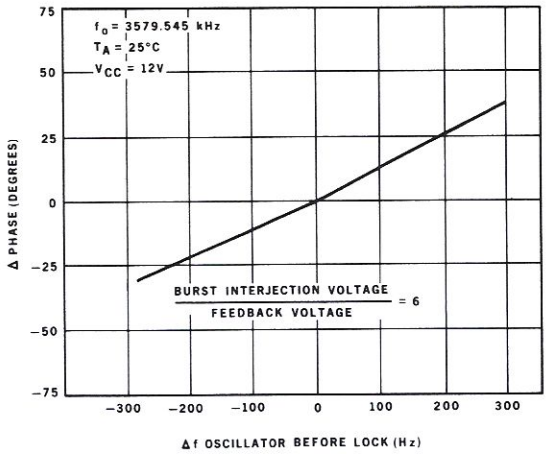
f_o = 3579.545 kHz
T_A = 25°C
V_{CC} = 12V
BURST INTERJECTION VOLTAGE / FEEDBACK VOLTAGE = 6
Δ PHASE (DEGREES)
Δf OSCILLATOR BEFORE LOCK (Hz)

Fig. 8. Phase shift versus oscillator free-running frequency, injection-locked oscillator.

much greater than measured oscillator drift due to all causes. Table II shows the free-running oscillator frequency for different μA703's with no current readjustments.

TABLE II.

Injection-Locked Oscillator--Frequency Variations with Several μA703's.

μA703 NO.	FREQUENCY OSCILLATOR(kHz)
6	3579.545
7	3579.455
8	3579.548
9	3579.508
10	3579.516
Conditions: V_{CC} = 12 V, T_A = 25 C	

NOTE: No circuit readjustments.

CONCLUSION

Two crystal oscillators, one voltage-controlled and the other injection-locked, have been designed, taking advantage of the self-limiting properties of the μA703 integrated circuit. Both oscillators are capable of excellent temperature stability and both have almost complete immunity to supply voltage variations. These two oscillators meet the requirements imposed by the chroma reference system for which they have been designed.